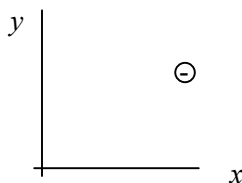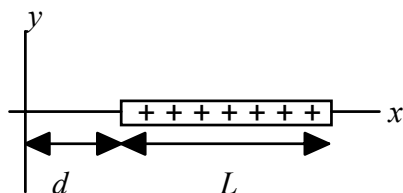**1.** The following statement is *true*.

A. If two initially uncharged objects are rubbed together and one of the objects acquires a positive charge, the other object also acquires a positive charge.

B. For separate point charges, the direction of the force between the charges is always along the line joining the two objects.

C. The net amount of charge produced in any process is not necessarily zero.

D. Like charges attract and unlike charges repel.

E. If a negative charge is brought near a "grounded" metal object, the metal object acquires a negative charge.

2. Two charged objects are initially 20.0 cm apart. They are moved and the magnitude of the electric force on each of them is found to have tripled. The final distance between the two objects is closest to

A. 8.3 cm.

B. 16.8 cm.

C. 6.7 cm.

D. 11.5 cm.

E. 14.4 cm.

3. A -1.0×10^{-10} C point charge is located at the point with coordinates $x = 0.40$ m and $y = 0.30$ m. The electric field at the origin is closest to

A. $(3.6\mathbf{i} + 3.6\mathbf{j})$ N/C.

B. $(5.6\mathbf{i} + 10\mathbf{j})$ N/C.

C. $(10\mathbf{i} + 5.6\mathbf{j})$ N/C.

D. $(2.9\mathbf{i} + 2.2\mathbf{j})$ N/C.

E. $(2.2\mathbf{i} + 2.9\mathbf{j})$ N/C.

4. The following statement concerning electrical conductors in static equilibrium is *false*.

A. The electric field just outside of a conductor is always perpendicular to the surface.

B. Any net charge on a conductor distributes itself on the surface.

C. The electric field inside a conductor is zero.

D. There can be no net charge at the surface of an empty cavity in a conductor.

E. The magnitude of the electric field just outside of a conductor is $\sigma/2\varepsilon_o$ where σ is the magnitude of the surface charge density.

5. A uniformly charged thin insulating rod has a total charge of $+Q$ and a length L. The rod lies along the x-axis and one end is a distance d away from the origin as shown in the diagram. The magnitude of the electric field at the origin is

y
+ + + + + + +   x
d   L

A. $\dfrac{1}{4\pi\varepsilon_o}\dfrac{Q}{d^2}$.   B. $\dfrac{1}{4\pi\varepsilon_o}\dfrac{Q}{L^2}$ C. $\dfrac{1}{4\pi\varepsilon_o}\dfrac{Q}{d(d+L)}$ D. $\dfrac{1}{\pi\varepsilon_o}\dfrac{Q}{(d+L)^2}$ E. $\dfrac{1}{4\pi\varepsilon_o}\dfrac{Q}{\left(d+\dfrac{L}{2}\right)^2}$

6. The solid circle represents the cross section of a spherical gaussian surface. There are charges of $+3.0$ C and -1.0 C outside the gaussian surface and $+2.0$ C and -5.0 C inside the gaussian surface as shown. The net (total) electric flux through the gaussian surface is closest to

A. 0.

B. -1.1×10^{11} V•m.

C. $+2.3\times10^{11}$ V•m.

D. $+1.2\times10^{12}$ V•m.

E. -3.4×10^{11} V•m.

Gaussian surface

-1.0 C   +2.0 C
$\ominus$ $\oplus$
            -5.0 C
+3.0 C $\ominus$
$\oplus$
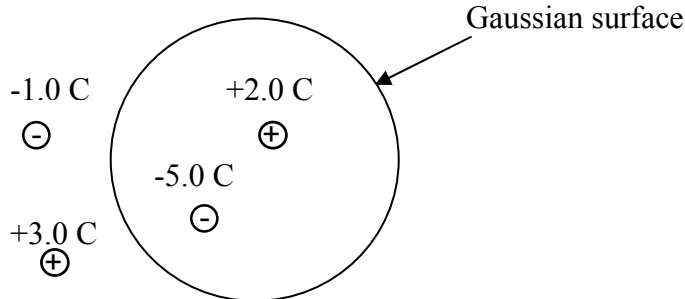
7. Point charges are located at the corners of an equilateral triangle of side 1.0 m as shown in the diagram. If $q = 3.0\times10^{-9}$C, the electric potential at the midpoint of the base (point P) is closest to

A. +31 V.

B. +21 V.

C. +15 V.

D. +10 V.

E. 0.

+q
$\oplus$
1m
$\oplus$ - - - • - - - $\ominus$
+q   P   -q
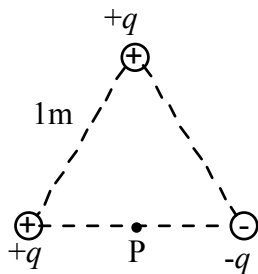
8. In the region of space where the electric potential is given by $V = (4y^2 + 6)$ volts and y is the y-coordinate with units of meters, the electric field is

A. $\mathbf{E} = (+4y\mathbf{j})$ N/C.

B. $\mathbf{E} = (-8y\mathbf{j})$ N/C.

C. $\mathbf{E} = (+6y\mathbf{j})$ N/C.

D. $\mathbf{E} = (-12y\mathbf{j})$ N/C.

E. $\mathbf{E} = (+10\mathbf{j})$ N/C.

9. Suppose that a –2.0 C charge is in a region of space where the electric potential is given by $V = (4y^2 + 6)$ volts. As the –2.0 C charge moves from a point at $y = 1.0$ m to a point at $y = 2.0$ m, the electric potential energy of the charge

A. does not change.

B. increases by 24 J.

C. increases by 36 J.

D. decreases by 24 J.

E. decreases by 36 J.

10. Three capacitors are connected to a 6.0 V battery as shown in the diagram. The capacitance of each capacitor is 0.10 F i.e. $C_1 = C_2 = C_3 = 0.10$ F. The equivalent capacitance and the total energy stored in the capacitors, respectively, are closest to

A. 0.45 F and 4.1 J.

B. 0.30 F and 2.7 J.

C. 0.30 F and 5.4 J.

D. 0.15 F and 1.4 J.

E. 0.15 F and 2.7 J.
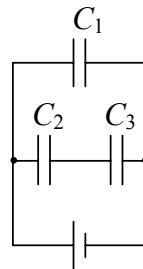
6.0 V

11. A parallel plate capacitor with vacuum between the plates is charged using a battery. The battery remains connected and a slab of insulating material (a dielectric) is inserted between the plates. As the dielectric is inserted, the following is true about the capacitor:

A. the capacitance decreases, the charge on the plates increases and the stored energy increases.

B. the capacitance increases, the charge on the plates increases and the stored energy increases.

C. the capacitance increases, the charge on the plates decreases and the stored energy increases.

D. the capacitance increases, the charge on the plates decreases and the stored energy decreases.

E. the capacitance decreases, the charge on the plates decreases and the stored energy decreases.

12. A heater wire (Nichrome) wire has a resistivity of $\rho = 1.0 \times 10^{-6}$ Ω·m at room temperature (20°C) and a temperature coefficient of resistivity of $\alpha = 4.0 \times 10^{-3}$ (C°)$^{-1}$. At 1000°C the wire has a length of 2.0 m and is cylindrical with a radius of 1.0×10^{-4} m. At 1000°C the resistance of the wire is closest to

A. 430 Ω.

B. 310 Ω.

C. 510 Ω.

D. 750 Ω.

E. 630 Ω.

13. There is alternating current (ac) in a 30.0 Ω resistor. The peak current is 0.60 A. The average power dissipated in the resistor is closest to

A. 5.4 W.

B. 3.6 W.

C. 1.8 W.

D. 0.94 W.

E. 10.8 W.

14. Consider the following circuit. When the switch is open the magnitude of the reading on the voltmeter is closest to

A. 0 V.

B. 6 V.

C. 3 V.

D. 12 V.

E. 9 V.
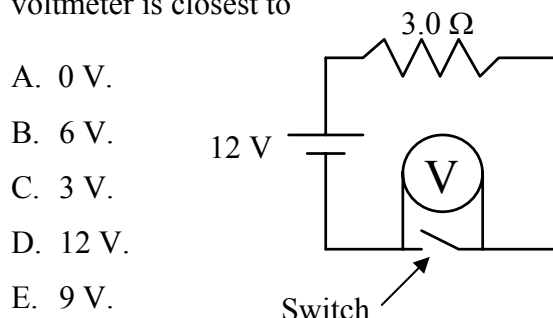
15. In the circuit shown below, a battery is connected to two resistors in series. The current in the 4.0 Ω resistor is 2.0 A. The magnitude of the terminal voltage of the battery is closest to

A. 10 V.

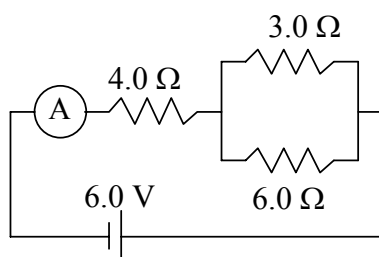B. 8 V.

C. 20 V.

D. 12 V.

E. 4 V.
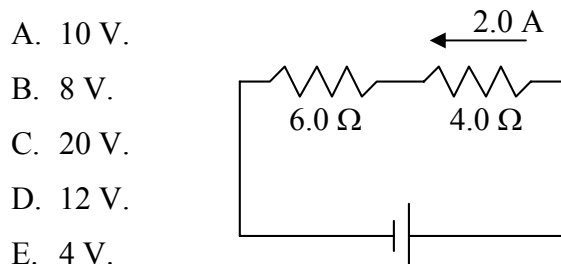
16. In the following circuits, all batteries are identical and perfect. Also, the construction of all light bulbs is identical. The circuit that contains the brightest light bulb is

A.   B.   C.   D.   E.
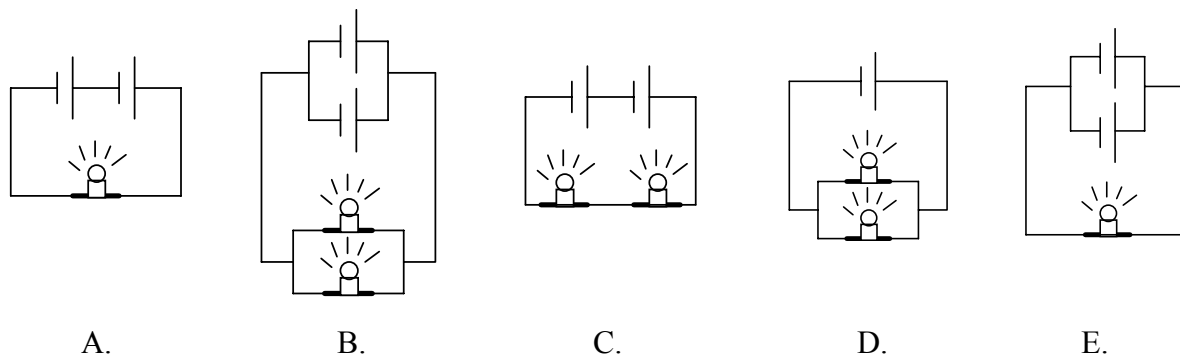
17. For the circuit shown below, the magnitude of the reading on the ammeter is closest to

A. 1.5 A.

B. 2.0 A.

C. 0.25 A.

D. 0.50 A.

E. 1.0 A.

3.0 Ω

4.0 Ω

6.0 V   6.0 Ω

18. Consider the *RC* circuit shown below. The switch has been in position 1 for a long time. At $t = 0$ the switch is moved to position 2. At $t = 4.0$ s, the magnitude of the current in the resistor is closest to

12 V

A. 0.88 A.

B. 0.41 A.

C. 0.067 A.

D. 0.59 A.

E. 0.20 A.

Switch

1   4.0 Ω   0.50 F

2
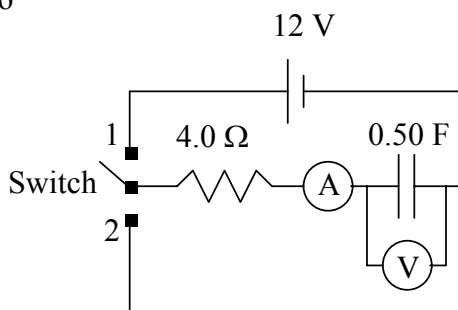
19. For the circuit, the current in the 1.0 Ω resistor is 1.0 A up. The current in the 3.0 Ω resistor is closest to

A. 3 A up.

B. 3 A down.

C. 2 A up.

D. 2 A down.

E. 1 A down.

7.0 V   5.0 V

2.0 Ω   1.0 Ω   1.0 A   3.0 Ω
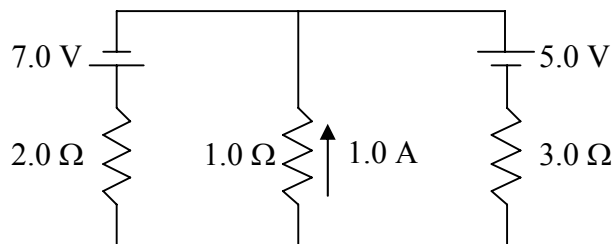
20. A +1.5 C charge moves through a region of space where there is a magnetic field **B** = (3.0**i** + 4.0**j**) T and an electric field **E** = (5.0**k**) N/C. At a given instant the charge's velocity is **v** = (6.0**i**) m/s. The total force on the charge at that instant is closest to

A. (+72**k**) N

B. (+66**k**) N

C. (+52**k**) N.

D. (+43**k**) N.

E. (+31**k**) N.

21. As in the lab Force Between Current-Carrying Wires, parallel wires carry equal currents in opposite directions. The following is the best representation of the magnitude of the force, *F*, on one of the wires vs. the current, *I*, in the wires


A.   B.   C.   D.   E.
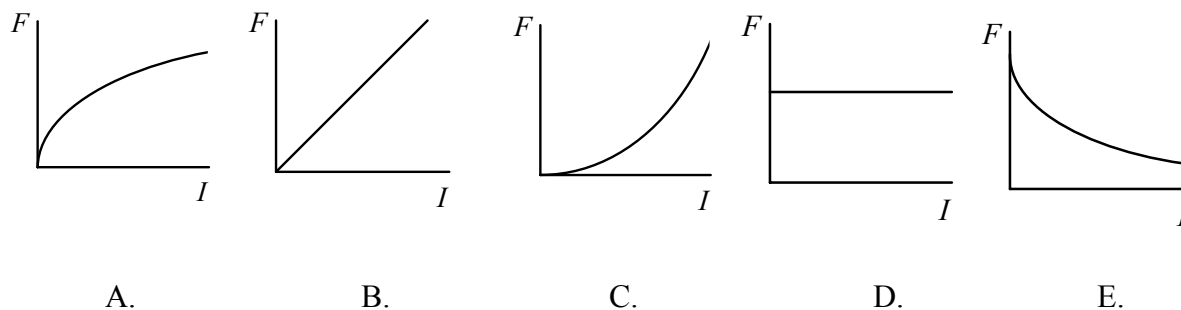
22. A uniform (constant) magnetic field of **B** = (7.00**j**) T exists in a region of space. A square of area 0.500 m^2 has two edges parallel to the z-axis and the other two edges are inclined at an angle of 30.0° relative to the y-axis as shown in the diagram. The magnitude of the magnetic flux through the square is closest to

A. 0.75 Wb.

B. 1.75 Wb.

C. 0.25 Wb.

D. 1.30 Wb.

E. 3.03 Wb.
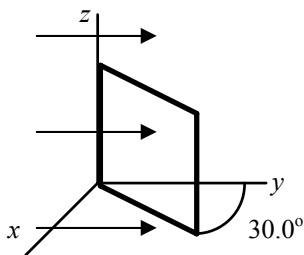
**23.** A proton ($q_{proton} = +1.60 \times 10^{-19}$ C, $m_{proton} = 1.67 \times 10^{-27}$ kg) is traveling in a constant magnetic field of 3.00 T into the page. At some instant, the velocity of the proton is 5.00×10^6 m/s toward the top of the page in the plane of the paper. The best description of the proton motion is that it travels

A. in a straight line.

B. in the plane of the page in a clockwise circle of radius 1.74 cm.

C. in the plane of the page in a counterclockwise circle of radius 1.74 cm.

D. in the plane of the page a clockwise circle of radius 1.04 cm.

E. in the plane of the page in a counterclockwise circle of radius 1.04 cm.


B into page
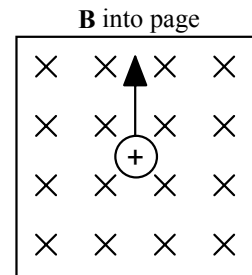
24. Two long thin parallel wires are 0.20 m apart. The upper wire carries a current of 15.0 A out of the page and the lower wire carries a current of 20.0 A into the page. The magnetic field midway between the wires (halfway from one wire to the other on a line joining the wires) is best given by

A. 0.

B. 7.0×10^{-5} T to the left.

C. 7.0×10^{-5} T to the right.

D. 1.0×10^{-5} T to the left.

E. 1.0×10^{-5} T to the right.

15.0 A

0.20 m

20.0 A
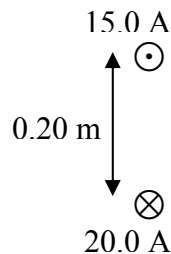
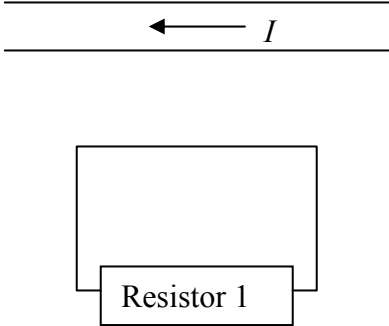**25.** A current loop (not shown) has a magnetic moment of $\mu = (5.0\mathbf{i})$ A·m^2. The current loop is in a magnetic field of $\mathbf{B} = (4.0\mathbf{k})$ T. The torque on the loop and potential energy of the loop, respectively, are closest to

A. $(-20\mathbf{j})$ N·m and -20 J.

B. 0 N·m and +20 J.

C. $(-20\mathbf{j})$ N·m and 0 J.

D. $(+20\mathbf{j})$ N·m and 0 J.

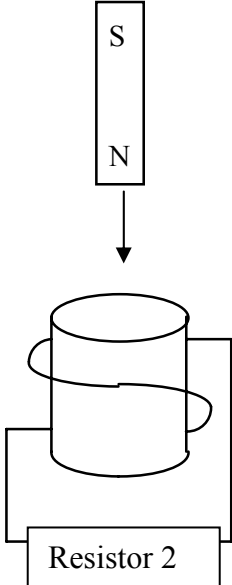E. $(+20\mathbf{j})$ N·m and -20 J.

z

B

μ

y

x
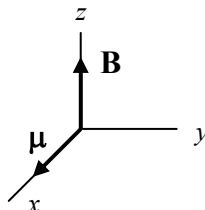
26. The following situations are separate. In the scenario on the left, there is a long wire where the current is to the left and decreasing. Below the wire is a circuit oriented as shown. In the scenario on the right, a magnet is moving toward a circuit as shown. The row in the following table that correctly gives the direction (or status) of the current in resistor 1 and the current in resistor 2 is

Current to the Left and Decreasing

$\longleftarrow\ I$

Resistor 1

Row	Direction of the Current in Resistor 1	Direction of the Current in Resistor 2
A	←	←
B	→	→
C	→	←
D	←	→
E	The current is zero.	The current is zero.

S

N

Resistor 2

**27.** Consider the *LR* circuit shown in the diagram. $R = 6.0\ \Omega$ and $L = 0.30$ H. The switch closes at $t = 0.000$ s. At $t = 0.050$ s, the voltage across the inductor is closest to

A. 3.8 V.

B. 2.2 V.

C. 5.7 V.

D. 3.3 V.

E. 0 V.

9.0 V

Switch

R

L
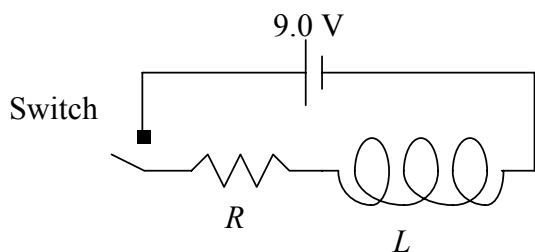
28. Consider the *LC* circuit shown in the diagram. $C = 0.50$ F and $L = 0.30$ H. The capacitor has a charge of 0.60 C before the switch closes at $t = 0.0$ s. After the switch closes, the maximum current in the circuit is closest to

A. 2.3 A.

B. 0.15 A.

C. 4.6 A.

D. 0.82 A.

E. 1.5 A.

C

Switch

L
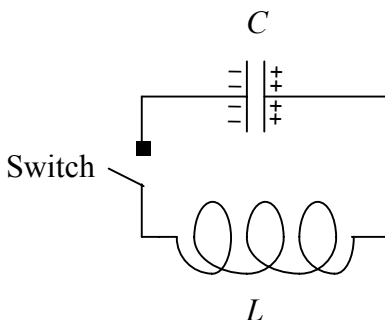
29. A transformer has 3 turns in the primary and 5 turns in the secondary. Even though only the transformer is shown, it is part of a circuit. An ac voltage of 12.0 V is applied to the primary and there is a current of 0.20 A in the primary. Assume that the transformer is 100 percent efficient. The ac voltage and ac current that appear in the secondary, respectively, are closest to

A. 20 V and 0.24 A.

B. 10 V and 0.24 A.

C. 3.6 V and 0.67 A.

D. 10 V and 0.12 A.

E. 20 V and 0.12 A.

3 turns   5 turns

Laminated
iron core
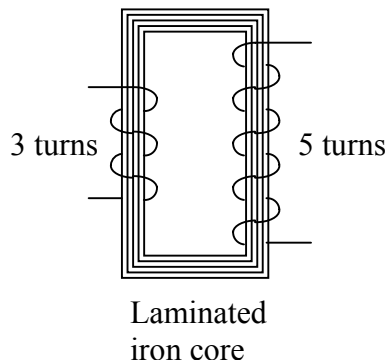
30. Consider a very long, tightly wound solenoid. The solenoid has a cross sectional area of $0.050 \ m^2$ and has 1000 turns per meter. There is a current of 2.0 A in the solenoid. The energy stored in a 0.1 m length of the solenoid is closest to

A. 0.013 J.

B. 0.022 J.

C. 0.035 J.

D. 0.050 J.

E. 0.068 J.

31. At a given instant, there is a 2.0 A current in the wires connected to a parallel plate capacitor. The plates are circular with an area of $0.50 \ m^2$. At the middle of the space between the plates, the magnitude of the rate at which the electric field is changing is closest to

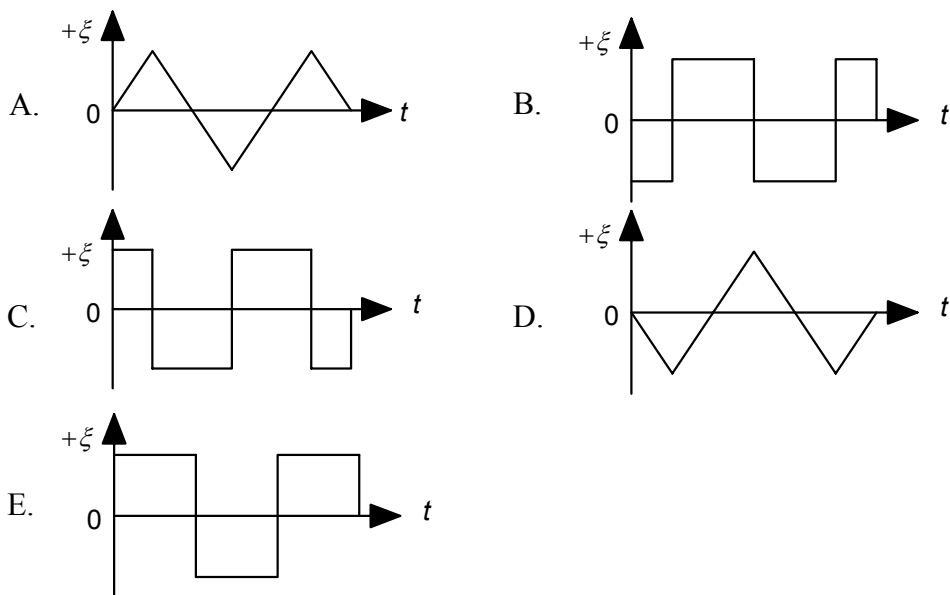A. 5.9×10^{10} V/(m·s).

B. 8.7×10^{10} V/(m·s).

C. 2.1×10^{11} V/(m·s).

D. 4.5×10^{11} V/(m·s).

E. 6.8×10^{11} V/(m·s).
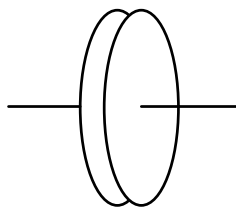
32. The magnetic flux vs. time in a coil is given by the following graph.

$+\Phi_B$

0 t
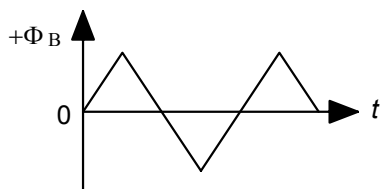
The graph that best represents the emf vs. time induced in the coil is

A. $+\xi$ 0 t

B. $+\xi$ 0 t

C. $+\xi$ 0 t

D. $+\xi$ 0 t

E. $+\xi$ 0 t

33. Consider a toroid with 100 turns where the inside radius, r_1, is 0.10 m and the outside radius, r_2, is 0.15 m. (A sketch of half of a toroid is shown below.) If there is a current of 3.0 A in the toroid, the magnitude of the largest magnetic field inside the toroid is closest to

A. 6.0×10^{-4} T.

B. 1.0×10^{-3} T.

C. 8.5×10^{-4} T.

D. 2.6×10^{-3} T.

E. 4.1×10^{-4} T.

r_2 r_1
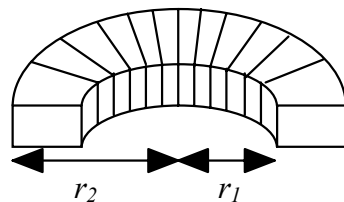
34. The following equation describes the experimental result that, in spite of intensive searches, no isolated magnetic poles (monopoles) have ever been observed.

A. $\oint \mathbf{E} \cdot d\mathbf{l} = -\dfrac{d\Phi_B}{dt}$

B. $\oint \mathbf{E} \cdot d\mathbf{A} = \dfrac{Q}{\varepsilon_o}$

C. $\oint \mathbf{B} \cdot d\mathbf{A} = 0$

D. $\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$

E. $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_o I + \mu_o \varepsilon_o \dfrac{d\Phi_E}{dt}$

**35.** An electromagnetic wave has a magnetic field given by $B_x = B_o \sin(ky + \omega t)$. The wave is traveling

A. in the $+x$ direction with a speed of ω/k.

B. in the $+y$ direction with a speed of k/ω.

C. in the $-y$ direction with a speed of k/ω.

D. in the $+x$ direction with a speed of k/ω.

E. in the $-y$ direction with a speed of ω/k.

36. Suppose that we know that the speed of light in a vacuum is $(3.00 \pm 0.01) \times 10^8$ m/s. If the speed of light in a material is found to be $(1.50 \pm 0.04) \times 10^8$ m/s, the refractive index of the material is best written as

A. 0.50 ± 0.05.

B. 0.50 ± 0.04.

C. 2.00 ± 0.04.

D. 2.00 ± 0.06.

E. 2.00 ± 0.05.

37. A double concave lens is made using a material with a refractive index of 1.20. The magnitude of the radius of the curvature of the front face is 20.0 cm and the magnitude of the radius of curvature of the back face is 30.0 cm. The focal length of the lens is closest to

A. -60 cm.

B. -300 cm.

C. -30 cm.

D. -150 cm.

E. +250 cm.

Double Concave
Lens
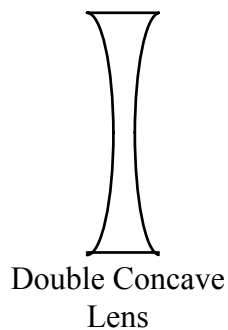
The next three problems are concerned with a beam of light in glass that strikes an interface with air as shown in the next diagram. (Yes, the flashlight is embedded in the glass.) The glass has a refractive index of 1.5 and air has a refractive index of 1.0.

38. If the beam of light in air has an angle of refraction of 70.0° (relative to the perpendicular to the interface), the angle of incidence (θ_{glass}) is closest to

A. 39°.

B. 37°.

C. 35°.

D. 33°.

E. 31°.
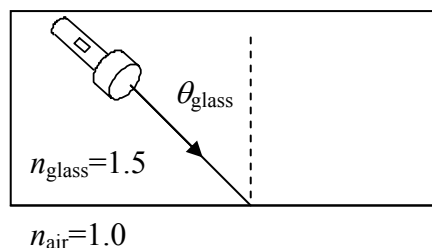
39. The smallest angle of incidence (θ_{glass}) for total internal reflection is closest to

A. 45°.

B. 42°.

C. 39°.

D. 36°.

E. 33°.

40. If the reflected beam is totally polarized, the angle of incidence (θ_{glass}) is closest to

A. 42°.

B. 48°.

C. 34°.

D. 56°.

E. 27°.

41. A mirror shows an upright image of a person who stands 1.5 m in front of it. The image is four times the person's height. The focal length of the mirror is closest to

A. +2.0 m.

B. +1.2 m.

C. +0.40 m.

D. +0.67 m.

E. +2.6 m.

The next two problems are concerned with the experimental setup shown in the diagram. An upright, 1.0 cm high object is 10.0 cm to the left of the lens and a real image is formed 20.0 cm to the right of the lens.
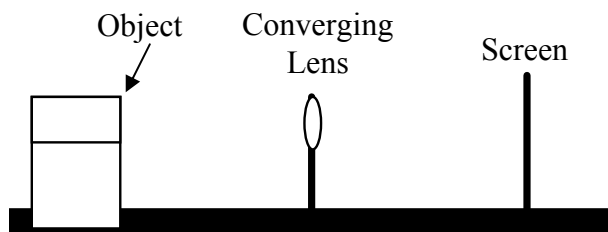
**42.** The focal length of the lens is closest to

A. +20.0 cm.

B. +5.9 cm.

C. +7.5 cm.

D. +15.0 cm.

E. +6.7 cm.

43. The image is

A. inverted and 2.0 cm high.

B. inverted and 3.0 cm high.

C. upright and 2.0 cm high.

D. upright and 3.0 cm high.

E. upright and 2.5 cm high.

44. A Young's double-slit experiment is performed with monochromatic light of wavelength 550 nm (5.5×10^{-7} m). The separation between the slits is 0.12 mm (1.2×10^{-4} m). The angle, θ, which is closest to that for second order constructive interference is

A. 0.41°.

B. 0.45°.

C. 0.49°.

D. 0.52°.

E. 0.56°.
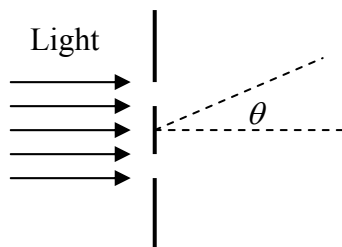
45. White light reflected from coated glass (and viewed approximately perpendicular to the surface) appears greenish yellow (λ = 570.0 nm is strongest). If the coating has a refractive index of 1.40 and the glass has a refractive index of 1.50, the minimum thickness of the coating is closest to

A. 238 nm.

B. 222 nm.

C. 204 nm.

D. 119 nm.

E. 102 nm

Air

Coating

Glass
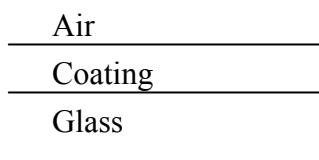
46. In a Michelson interferometer, 1000 fringes of 400.0 nm light pass by a reference. The distance that the mirror M_1 moves is closest to

M_1 (movable mirror)

A. 0.60 mm.

B. 0.40 mm.

C. 0.30 mm.

D. 0.20 mm.

E. 0.10 mm.

M_S

Source

M_2
(fixed mirror)

Eye
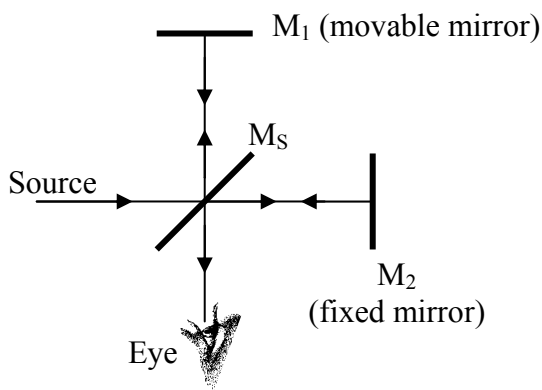
47. Light passes through a single slit 8.0×10^{-6} m wide. The first minimum is 2.0 cm away from the central maximum on a screen that is 30.0 cm away from the slit. (The figure is not drawn to scale.) The wavelength of the light is closest to

A. 403 nm.

B. 532 nm.

C. 667 nm.

D. 466 nm.

E. 614 nm.

First Minimum

Light

2.0 cm

Central Maximum

30.0 cm

Screen
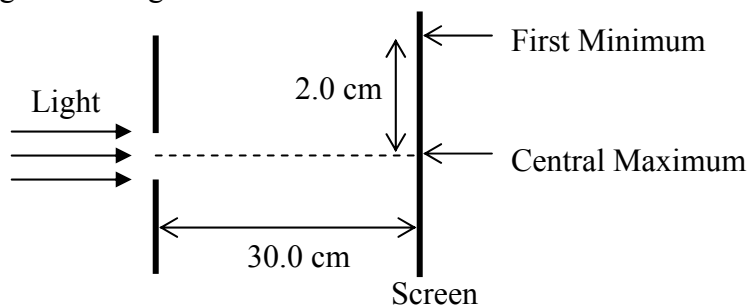
48. The Hubble Space Telescope has an objective diameter of 2.4 m. (Assume that there is a circular opening of 2.4 m.) The angular resolution limit set by diffraction of light of wavelength 500.0 nm is closest to

A. 4.5×10^{-7} rad.

B. 4.0×10^{-7} rad.

C. 3.5×10^{-7} rad.

D. 3.0×10^{-7} rad.

E. 2.5×10^{-7} rad.

49. Light of wavelength 700.0 nm is incident on a transmission diffraction grating with 800 slits per mm. The highest order constructive interference that can be observed is

A. first order.

B. second order.

C. third order.

D. fourth order.

E. fifth order.

50. Unpolarized light of intensity I_o passes through two successive Polaroid sheets. The axis of the second Polaroid sheet is at an angle of 60.0° relative to the axis of the first Polaroid sheet. The intensity of the transmitted beam is closest to

A. $0.75\ I_o$.

B. $0.062\ I_o$.

C. $0.25\ I_o$.

D. $0.50\ I_o$.

E. $0.12\ I_o$.

Polaroid Sheets

60°

Unpolarized light of intensity I_o
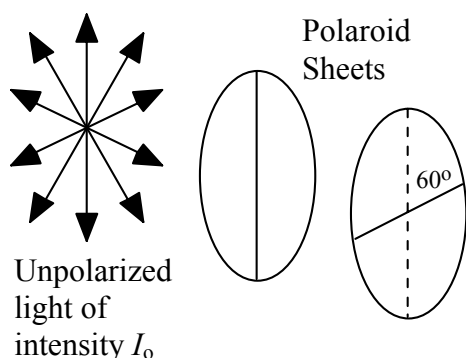
Instructions for filling out the SCANTRON answer sheet

1. Please fill out the form completely but *only write or mark in the spaces provided.* (Please do *not* make extra marks on the form.)

2. Please fill in the bubbles completely as shown in the example on the form. If you make a mistake, either erase completely or obtain a new form.